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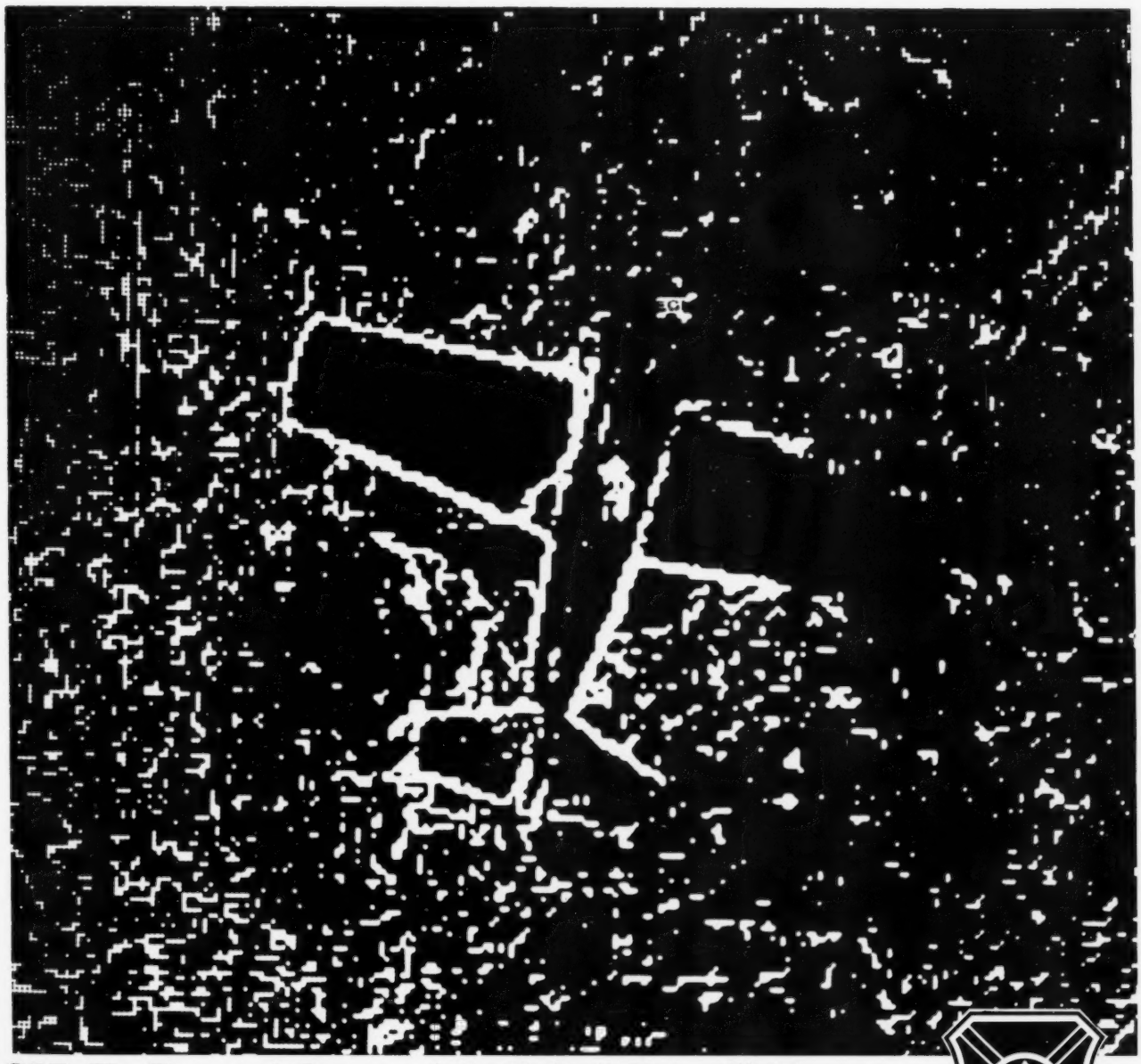
# OAR RESEARCH REVIEW

## OFFICE OF AEROSPACE RESEARCH ★ UNITED STATES AIR FORCE



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Volume VIII Number 2 March-April 1969

# OAR RESEARCH REVIEW

VOLUME VIII NUMBER 2 Mar-Apr 1969


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**ON THE COVER:**

Manual scanning of reconnaissance photographs is extremely tedious, often requiring literally hundreds of photo interpreters for a given military situation. Photo analysis and interpretation can be computerized, and scientists at AFCRL are attempting to do exactly that. The cover photo shows the outline of an airplane after computer processing of an original photograph. The original photograph had extremely poor definition and contrast, with part of the aircraft being obscured. Following computer processing, the wing, tail, and fuselage structures were greatly enhanced and transformed into a pattern amenable to computer recognition.

OARRP 80-1

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JACOB SEIDEN *Editor*

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# Auger electron spectroscopy

DR. T. W. HAAS
Chemistry Research Laboratory, ARL

In recent years a number of important techniques have become generally available for solid-surface studies. Included in these are low-energy electron diffraction, (LEED) (1), field electron and field ion microscopy, Mössbauer-effect studies, electron paramagnetic resonance, and others. These developments are of importance because many problems of relevance to Air Force technology are found on surfaces. A few of these are epitaxy and its relationship to thin-film and microelectronic devices, optics, corrosion, catalysis, and friction and wear characteristics. The precise characterization of a surface, structurally and electronically, has lagged behind such developments for the molecular state and for the bulk solid state. Accordingly, our ability to understand surface phenomena, control these phenomena, and tailor surfaces to our specific needs is considerably far behind our capabilities for doing so with molecules and bulk solids. The aforementioned techniques should provide the groundwork for progress in this important area. Lacking in the studies thus far, however, has been an effective means for the qualitative analysis of surface impurities that can be performed on the sample while it is being studied by one or another technique.

Recent work using LEED equipment has given at least a partial solution to the qualitative-analysis problem. The key to the technique is measurement of the inelastic current scattered from the surface rather than the elastic current involved in the diffracted beams. (2) Consider the fate of an electron incident on a solid surface. If the surface is crystalline, the electron may be elastically scattered (no loss of energy in the collision) and go into one or another diffracted beam. Alternatively, it may undergo an inelastic scattering event. There are many such processes which comprise the group of inelastic collisions. These include electron-electron, electron-phonon, electron-photon, and other interactions.

The electron-electron interaction of interest is the Auger transition, which can be described as follows. The incident electron excites an electron from a lower energy level in the solid—a tightly bound core electron—to a higher energy state (see Figure 1).

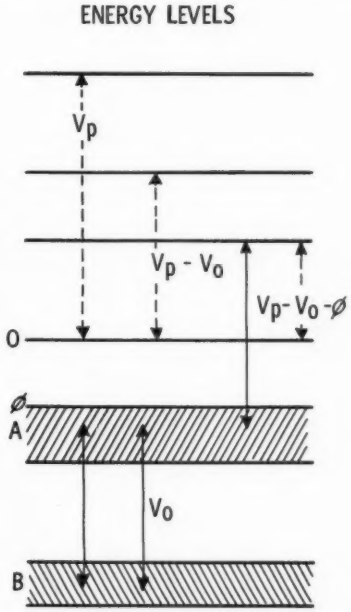


**Figure 1. Schematic representation of the Auger process. The vacuum level is zero. Electrons of energy Vp are incident on the sample and excite electrons from band B into band A. This energy is given to an electron in the solid near the Fermi level, $\phi$, which is then ejected from the solid with energy Vp-Vo-$\phi$.**

The energy gained by this electron is then given up in several ways as this electron falls back into its ground state. If the energy is given off as photons, then we have the characteristic emission spectrum of the material (wavelengths from the visible to the X-ray region). Alternatively, this energy may be given to an electron near the Fermi level. Since the energy involved is usually much greater than the work function of the material, the electron receiving this energy can be ejected from the solid with an energy equal to the difference between the energy of the transition and the work function of the material. Further, the energy levels concerned usually involve the inner-core electrons, and since these energy levels are little affected by being condensed in a solid, they should be characteristic of the material excited. Obviously there are a number of such processes that are possible, and indeed more than one group of such electrons are observed for each material. (3) At present, work is in progress in several laboratories to determine the strongest "lines" for each element.

The experimental technique which allows the measurements to be made is of some interest in itself. (4,5) Commonly a three- or four-grid display-type LEED system is utilized with the middle (suppressor) grid used for energy selection by applying a varying retarding potential to it. The inelastically scattered electrons are collected on the fluorescent screen. In principle, the current-voltage curve obtained has the information sought; but stability and noise make such curves of little use in practice. The trick to success is to apply a small a.c. modulating signal on the suppressor grid and thus detect the a.c. component of current at the fluorescent screen using a phase sensitive lock-in type amplifier. The first harmonic of the signal is proportional to the number of electrons in a given energy range. It can be shown that the second harmonic is proportional to the derivative of this energy-distribution curve, and this signal is the one usually followed. This is done since the second derivative reduces background problems, hence allowing higher gains and finer structure to be obtained.

An example of the usefulness of this technique is the recent development in studies of silicon surfaces. Early LEED studies indicated that the silicon (111) surface was rearranged into a surface structure having the same symmetry as a bulk (111) plane, but with dimensions 7 times as great. (6,7) Recently a number of workers have examined this surface with both LEED and Auger electron analysis,

and have found extra peaks due to iron and nickel when the (7X7) structure appears. (8,9) This may indicate that the clean Si (111) surface is not rearranged in the absence of stabilizing impurities. Another structure has been found on the Si (111) surface in this laboratory due to tantalum contamination, presumably from the leads connected to the sample. A typical Auger spectrum is shown in Figure 2 with the Ta and Si peaks identified. The Ta peaks were known from a previous study of the Ta (112) surface. (10)

These observations of metal contaminants on what were otherwise thought to be clean surfaces can be of very great importance technologically. It is well known that very small amounts of such materials can have a profound influence on semiconductor devices. It is entirely possible that such contaminants are present in all currently manufactured devices, and have an influence on them.

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*Dr. T. W. Haas was appointed to the position of Task Scientist in ARL's Chemistry Research Laboratory in April 1964. His work at the laboratory has been concerned primarily with studies of the physics and chemistry of clean solid surfaces. The major current project has concentrated on structure determinations of solid surfaces, both clean and with chemisorbed gas layers. Low-energy electron diffraction has been the major tool used in this work.*

*Prior to joining ARL, Dr. Haas was employed by the National Cash Register Company in their Fundamental Research Department. His work there was primarily concerned with properties of materials in the solid state. He was also employed by the Socony Mobil Oil Company at their Field Research Laboratory from March 1960 to December 1962.*

*Dr. Haas received his B.S. degree from St. Mary's University in San Antonio, Texas in 1954. After graduation, he served two years in the U.S. Army, and then entered graduate school at the Iowa State University of Science and Technology. He received a Ph.D. degree in March 1960, with a major in Physical Chemistry. While at Iowa State, he was employed as a graduate research assistant by the U.S. Atomic Energy Commission through the University.*

*Dr. Haas is a member of the Scientific Research Society of America, the American Physical Society, and Phi Lambda Upsilon and Phi Kappi Phi Honorary Scholastic Societies. He has a number of publications to his credit.*

**Dr. Haas using the LEED apparatus for Auger electron spectroscopy.**

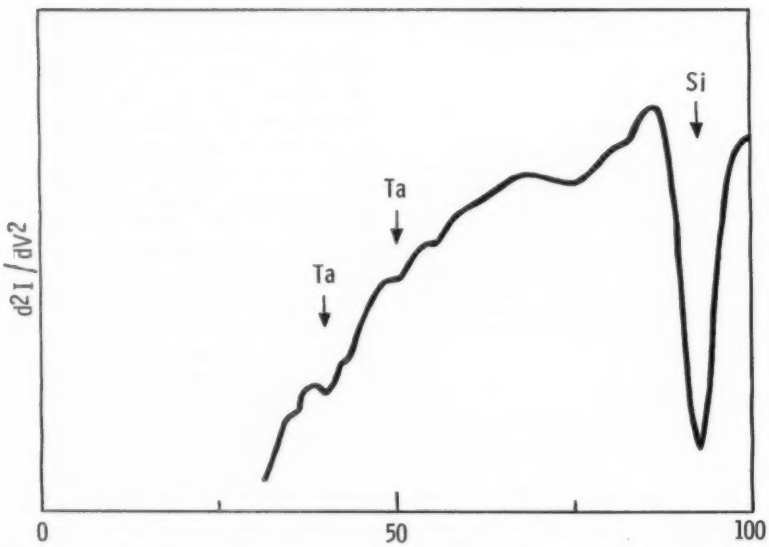



**Figure 2. Portion of the Auger spectrum from a Si(111) surface contaminated with Ta. The major peak in the spectrum, at about 90v, is due to Si. Two of the peaks due to Ta are also identified. Primary beam energy was 500 volts. (The author wishes to thank Dr. J. Grant of ARL for his permission to use this figure prior to its publication).**

# new instrument for measuring the acceleration of gravity

TERRESTRIAL SCIENCES LABORATORY, AFCRL

A new gravity-measuring apparatus—the most precise gravity-measuring instrument ever developed—was installed in January 1969 at the Air Force Cambridge Research Laboratories, Bedford, Mass. The measuring technique, in principle, is simple. An object is dropped and the experimenter clocks its rate of fall. In so doing, he is using the method used by Galileo who made the first gravity measurements more than 300 years ago.

Instruments for measuring gravity (actually the acceleration of gravity is measured) haven't changed much in principle since then. We can either time the rate of fall of a free-falling body, or we can time a falling body whose motion is constrained. The pendulum, which was first used to measure gravity in the 17th Century, is a classic example of a falling body under constraint. It has been greatly refined over the years, and its precision is approaching theoretical limits.

The new instrument installed at AFCRL is of the free-fall type. It was developed for AFCRL and the National Bureau of Standards by James E. Faller of Wesleyan University.

The apparatus, shown in Figure 1, has a vertical length of 10 feet. It is essentially a Michelson-type interferometer with a helium-neon light source. It is called the laser-interferometer apparatus. The heart of the system is an evacuated ($5 \times 10^{-7}$ torr) 4-foot drop chamber. Associated with the apparatus is an array of electronic timing gear. At AFCRL, the apparatus was placed on a concrete seismic pier built on bedrock. Part of the apparatus itself is a seismometer for sensing and correcting vibrations.

The development of the apparatus had to await two technologies, neither of which was available until after World War II. One was the electronic technology needed for measuring extremely short time intervals; the second was the laser technology that made possible a monochromatic light source which could produce sharp, well-defined interferometric fringes.

To measure gravity by the interferometric method, one mirror of a Michelson interferometer is dropped in free fall. This produces a rapidly varying fringe pattern. The problem with dropping a flat mirror of the type ordinarily used in a Michelson interferometer is that, if one side of the falling plate gets ahead of the other side by only half a wavelength, system performance is degraded.

What is needed then is a falling-mirror system that is totally insensitive to any misalignment that might occur during free fall. The problem is solved in the laser-interferometer apparatus by using a mirrored corner-cube. Light from such a falling cube is always reflected in a uniform direction, even if the cube tilts slightly during its 1-meter fall.

The output from the interferometer, of sinusoidally varying intensity, increases in frequency during the free fall of the corner cube. The light and dark oscillations produced by

**Figure 1. The gravity-measuring device consists of a Michelson-type interferometer using a helium-neon light source. One mirror of the Michelson interferometer is dropped the 10-foot length of the apparatus in free fall. This produces a rapidly varying fringe pattern which is used to time the rate of fall of the mirror with extreme precision.**

the rapidly changing fringe pattern are detected by a photomultiplier and counted by an electronic timer with a timing accuracy of about one nanosecond.

Initial measurements with the instrument suggest that it is capable of a precision approaching one part in a hundred million. By comparison, the accuracies of pendulums are a few parts in a million. With its high degree of accuracy, the new laser-interferometer apparatus will be capable of measuring the minute (several parts in 10 million) tidal variations caused by the attraction of the sun and the moon with greater precision than any previous absolute gravity instrument.

To establish gravity values for a particular location, many measurements must be made and an average obtained. This will be the procedure at AFCRL. The AFCRL site will then become a standard to which other gravity-measuring instruments can be brought for calibration. There are only about ten sites in the world where gravity values are known with sufficient accuracy to serve as standards.

The laser-interferometer apparatus will remain in place at AFCRL only until the gravity value at the site has been established with extreme precision. AFCRL will then move the apparatus to other locations for similar measurements.

In an article in Science, Faller, who developed the apparatus, looks into the future where, he states, "it is not unreasonable to speculate that before many years, free-fall measurements will achieve an accuracy of 1 part in a billion. At this level of precision, a number of effects of geophysical and possibly cosmological origin may be expected to appear."

The AFCRL gravity-measuring program, which includes both the development of new gravity instruments and the use of these instruments to measure gravity values at many locations, is under the direction of Bela Szabo.

**Mr. Szabo consults a standard reference work on gravitation,** *International Gravity Measurements.*

*Mr. Bela Szabo, Chief, Gravity Branch, Terrestrial Sciences Laboratory, AFCRL, directs basic and applied research on the external gravity field of the earth and in the area of physical geodesy. This work includes theoretical research and research on mathematical methods, measuring instruments, and observational techniques. Results are applied to improve gravity-dependent earth constants and geodetic parameters. Mr. Szabo, who received his Dipl. Ing. from the University of Budapest in 1938, is particularly interested in gravitational effects and their use in inertial navigation and space programs.*

# DUST AT HIGH ALTITUDES

OPTICAL PHYSICS
LABORATORY, AFCRL

If we look carefully toward the horizon soon after sunset, we can sometimes see faint, dark bands stretching across the orange sky. These subtle bands are aerosol concentrations in the upper atmosphere. Such aerosols are of military concern because they obscure the view of optical instruments designed for surveillance and detection.

Louis Elterman of AFCRL is studying these aerosols to obtain data on just how much they attenuate optical radiation. Those in other disciplines may find the study of aerosols valuable for other reasons. Aerosol concentrations could serve as tracers for the meteorologist studying the movement of air masses and other atmospheric processes. Climatologists have frequently speculated that long-term increases in aerosol concentrations resulting from man-made pollutants could possibly modify the earth's weather; thus aerosols relate to problems in air pollution. A recent report by University of Wisconsin meteorologists indicates, in fact, that there has been an increase in aerosols during a 10-year observational period beginning in 1957.

The altitude range considered by Elterman extends up to about 35 km. Most of the dust above altitudes of about 5 km or so has been transported there from the surface by convection currents or by volcanic eruptions. But some of the dust is the residue of meteors, and may even be produced *in situ* from atmospheric gases.

Rockets, satellites, and aircraft have all been used to measure atmospheric aerosol concentrations. Another method of measurement, the ground-based searchlight technique developed by Elterman, is far less costly and has proven to be uniquely productive. For the past several years, AFCRL has made measurements in New Mexico in which the beam of a powerful searchlight is pointed upward. (See Figure 1.) Using an optical telescope at AFCRL's Sacramento Peak Observatory 30 km distant, the beam is

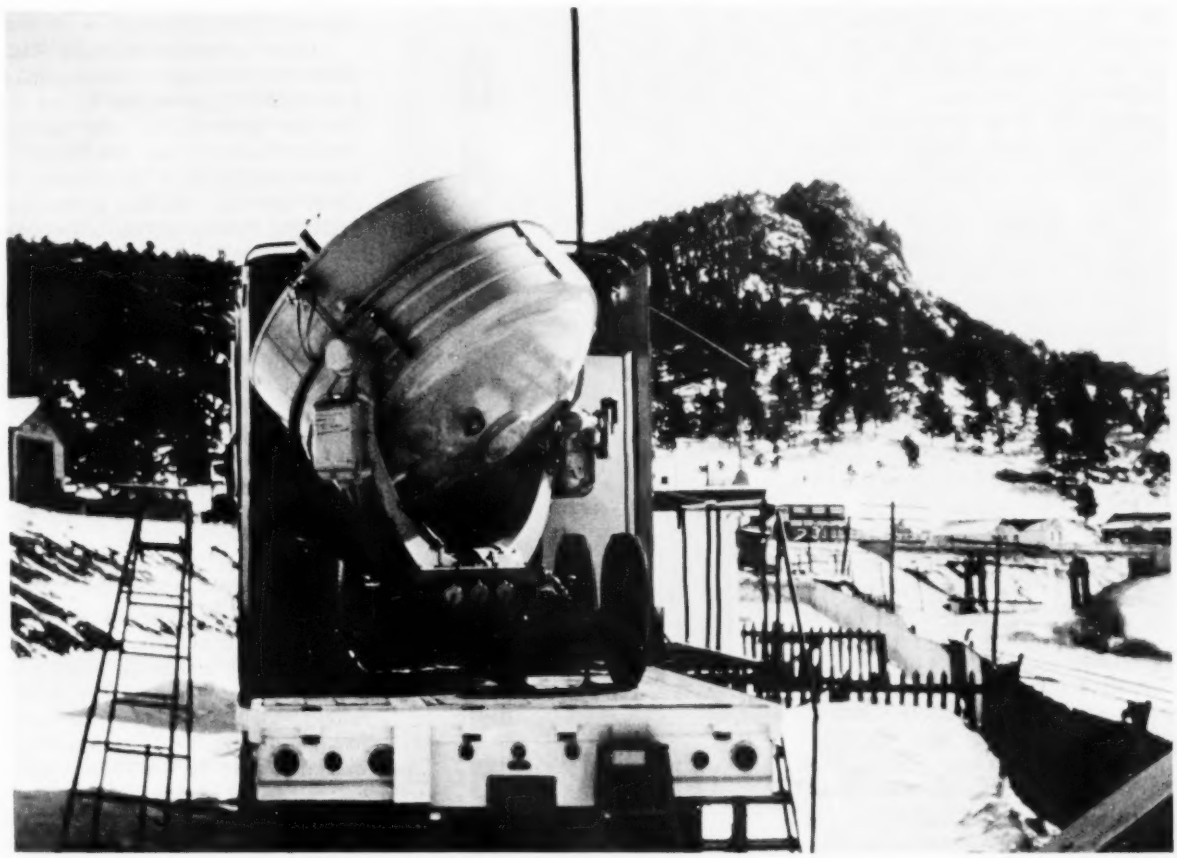


**Figure 1. This narrow-beam searchlight at White Sands, N.M., was used by AFCRL to measure the aerosol content of the atmosphere. Backscattered light from the searchlight beam was observed and recorded 30 km away at AFCRL's Sacramento Peak Observatory.**

scanned to determine the amount of light scattered from the beam at various altitudes. The amount of light scattered corresponds fairly closely to aerosol concentration. By this method, Elterman has obtained more than 150 vertical profiles of atmospheric aerosols.

Aerosol concentrations over New Mexico are marked by variability. Elterman attributes this variability to the day-to-day ebb and flow of tropical and polar air masses over the area. Aerosols tend to concentrate at the tropopause where temperatures, after decreasing with altitude to a minimum, begin to rise. But when both tropical and polar air masses are present overhead, there is a tropical and an arctic tropopause. A polar tropopause, marked by a slightly rising temperature, occurs at 12 km. After this temperature increase, the temperature decreases again with altitude until the colder tropical tropopause is reached at an altitude of about 18 km. In this situation, a peak in aerosol concentration is found at both the tropical and arctic tropopause, with the stronger concentration occurring at the higher and colder tropical tropopause.

These findings suggest that the aerosol particles are transported from the lower to the higher altitudes by convection, and that most aerosols have originated from the earth's surface at tropical and semitropical latitudes where the convection is more intense. As the tropopause is approached, the rising air begins to spread out laterally—transporting and depositing particulate matter as it does so.

Volcanic eruptions can greatly enhance aerosol concentrations. Observations of dust from the March 1963 Mt. Agung eruption in the East Indies showed that the dust persisted for more than a year, and was probably responsible for a dust belt observed in the stratosphere at 26 km. This 26-km dust belt is puzzling since there is ordinarily little transport of tropospheric air into the stratosphere. There is no fully satisfactory explanation of how aerosols gain admittance to the stratosphere and why they form into a distinct belt.

# balloons on a tether

## AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

Captive or tethered balloons can be sent to altitudes of 10,000 feet without difficulty. Balloon designers and engineers are now looking into the future when it may be possible to suspend balloons on a tether at altitudes of 100,000 feet.

Under construction at the White Sands Missile Range in New Mexico is a new AFCRL permanent launch site for the development and test of tethered balloons. The site should be fully operational in the summer of 1969. Over the next several years, as skills and balloon-system designs improve, tethered balloons will be sent to higher and higher altitudes from this site.

Problems and possible solutions associated with the goal of sending tethered balloons to extreme altitudes were reviewed by Capt. Edward F. Young of AFCRL in a paper delivered at the AIAA 2nd Aerodynamic Deceleration Systems Conference held at El Centro, California, on 23 September 1968.

The most important military application of tethered balloons is their use as communications relay platforms. They could also serve, when equipped with appropriate sensors, as unmanned surveillance vehicles. In this respect, they would have the same function they had in 1794, when they were first used by the French Army for battlefield observation. Tethered balloons were extensively used during World War I for the same purpose, and during World War II they were used to protect against low-flying aircraft.

Thus, they have a long military history.

In his AIAA paper, Capt. Young reviewed such considerations as the physical constraints imposed by the weight of the cable, the design of the balloons for various altitudes and payloads, and climatological factors that must be known for a given operational location.

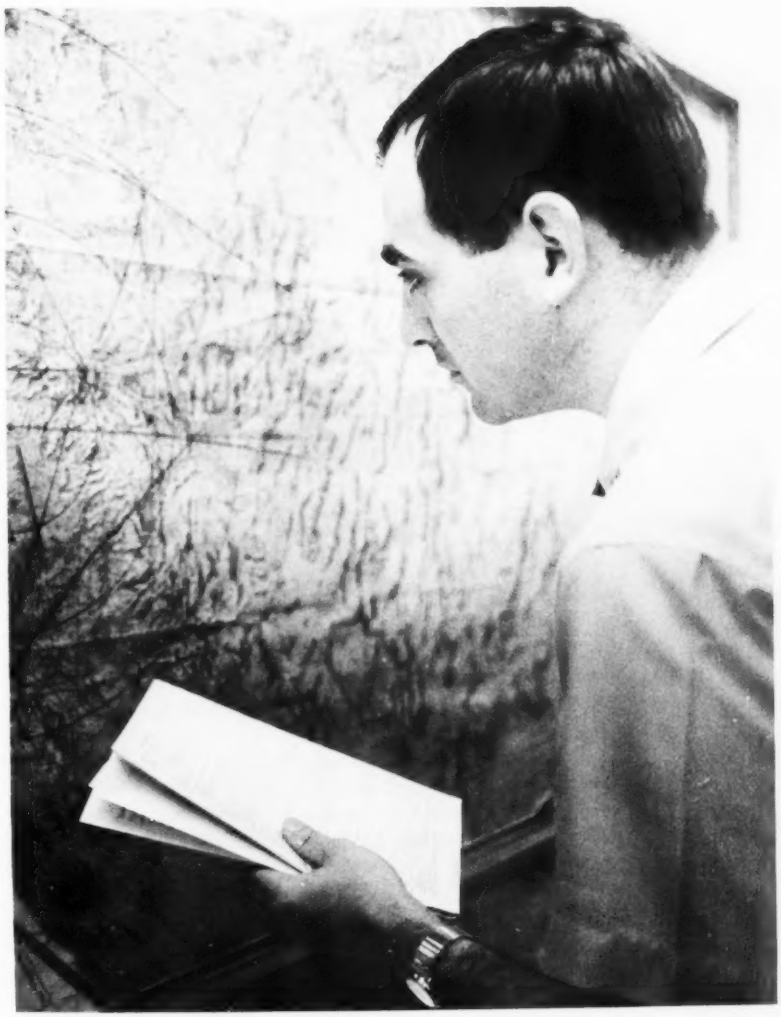
The cable material is the most critical component in a high-altitude tethered-balloon system. Although high strength-to-weight is important, it is not decisive. All cable materials are subject to creep rupture, resulting in failure of the cable after a period of time under a static load. But some materials, such as Nylon, are especially susceptible to such rupture. A good cable material must be flexible, non-crimping, and easy to reel and unreel. Of the materials tested—Mylar, braided Nylon, carbon steel, stainless steel, and Dacron—the best strength-to-weight material is glass fiber, although it is not best in other respects.

The design of the balloon depends on such requirements as downwind displacement, altitude, payload, flight duration, and anticipated life. Thus, experimental tethered balloons may be spherical, natural (onion-shaped), single-hull (blimp-shaped), or v-shaped. The spherical shape is easier to fabricate and costs less, but its use is limited to winds below 30 knots.

Before a balloon is designed for a particular requirement, the designer must know the climatology of the location at which it is to be flown. The pattern of average wind speeds during a given month or season is the basic factor. For example, given the mean wind at a given location, what system design will assure that the system can be flown 50 percent of the time? The operator must also know the answer to such questions as: If the wind speed is now X knots at a given altitude, what is the probability of flying the balloon for 10 hours?

In discussing future balloon capability, Capt. Young notes that it may be easier to maintain a tethered balloon at 60,000 to 70,000 feet than at altitudes between 30,000 and 50,000 feet because of the strong prevailing winds found in the lower altitude range. The problems of getting the balloon through the high wind regime, however, remain to be solved. To reach 100,000 feet, a two-balloon system is essential. One scheme calls for reeling out a natural-shaped balloon to an altitude of about 70,000 feet. Then the cable is attached to a blimp-shaped balloon which is reeled out another 20,000 feet or so. The entire system could reach a maximum potential altitude of about 100,000 feet. The development cost for such a two-balloon system would be relatively expensive—more than $2 million.

During the next several years, from the AFCRL tethered-balloon experimental site in New Mexico, Capt. Young and others at AFCRL will test many of the balloon designs and tethering concepts outlined in the AIAA paper.



*Capt Edward F. Young is an aerospace engineer with the Balloon Research Branch, Aerospace Instrumentation Laboratory, AFCRL. He attended Rensselaer Polytechnic Institute, receiving his BAE in 1959. In 1966 he received an M.S. in Aerospace Engineering with Distinction from AFIT.*

*Previously, Capt Young was an aircraft maintenance officer with SAC & AFSC; a performance engineer with AFFTC, Edwards AFB; and an Aeronautical Engineer, Flight Research, at Edwards AFB. Prior to entering the service, he was employed by Lockheed California Co. as a propulsion analyst.*

*Presently, Capt Young is working toward the development of a high-altitude tethered-balloon system. He is a member of the American Institute of Aeronautics & Astronautics.*

AERONOMY LABORATORY, AFCRL

# ULTRAVIOLET SPECTROSCOPY AND THE GUENTER LOESER AWARD

Spectroscopy is the common bond of many AFCRL programs in experimental physics. Few research laboratories in the world have made more contributions to ultraviolet spectroscopy than AFCRL, especially in the application of ultraviolet spectroscopy to the chemistry of the atmosphere.

Techniques and knowledge originated at AFCRL have been widely adopted by instrument manufacturers and by researchers in university, Government and industrial laboratories. AFCRL spectroscopists have discovered or measured with greater precision thousands of emission and absorption lines and bands, absorption cross sections, and associated energy levels.

AFCRL has studied the ultraviolet spectroscopic properties of all of the common atmospheric gases—$N_2$, $O_2$, O, $O_3$, CO, $CO_2$, $H_2O$, N, Ar, and $H_2$. These studies have revealed structural details never before observed. For atomic oxygen alone, AFCRL has recently discovered 176 new energy levels, which more than doubles the known levels. Such studies are a fundamental step in the understanding of such atmospheric processes as photoionization, photodissociation, and photoexcitation, and the formulation of a consistent model of atmospheric absorption.

Many of AFCRL's successes in ultraviolet spectroscopy have been due to the work of Dr. Robert E. Huffman. For his contributions, on 5 November 1968 Dr. Huffman received the 1968 Guenter Loeser Memorial Award. This award has been made annually since 1955 to an AFCRL scientist in recognition of research of high merit. In the 14 years of the annual Guenter Loeser Award, 4 AFCRL scientists working in the field of ultraviolet spectroscopy have received the award—a disproportionate number when considered against the total scope of AFCRL programs. AFCRL's contributions to this field have been made both in instrumentation and in the use of that instrumentation to obtain improved spectra of gases.

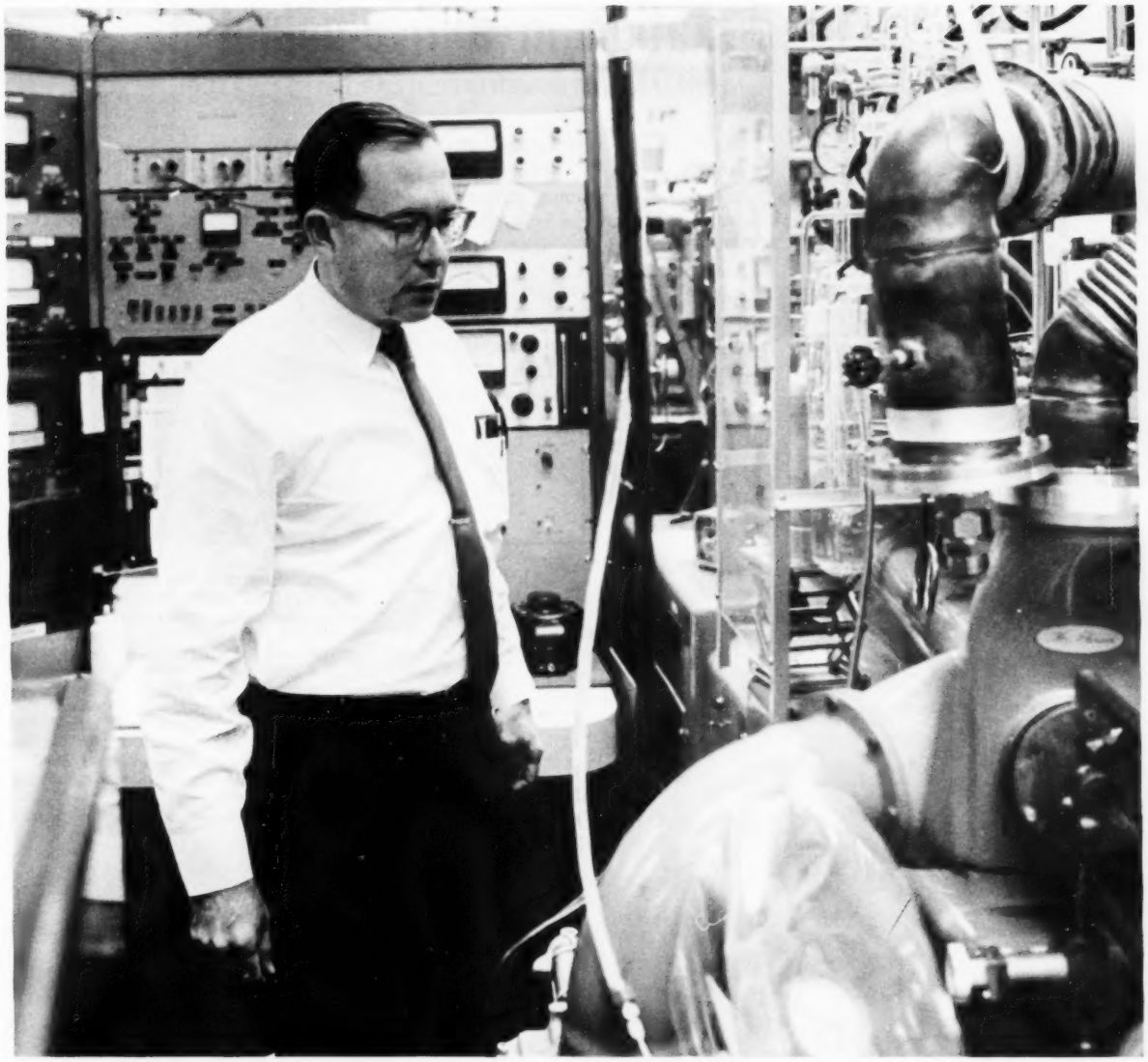
The research that led to the 1968 Guenter Loeser Award involves ultraviolet-light sources for obtaining absorption spectra of sample gases. The light sources of interest to Dr. Huffman are known as rare-gas continuum light sources. Let's explain these sources. As we know, an excited rare gas, such as neon and xenon, glows. As we also probably know, the radiation from the gas does not occur uniformally, but occurs at a group of fixed wavelengths characteristic of the gas. Nevertheless, within this emission spectrum, we may find a region where, over a given range, emission takes place at all wavelengths. This region is known as a continuum. It is this continuum which, after proper filtering, is passed through a sample gas to obtain an absorption spectrum.

The first rare-gas continuum to be discovered, in 1930, was the Hopfield helium continuum. This continuum is found in the 600- to 1000-angstrom region. Since then, continua at other wavelength regions have been found for neon, argon, krypton, and xenon. These continua have a very low light intensity. Another problem is instability. Instability results from the fact that the rare gas is excited by a rapidly pulsed capacitor discharge. The instability occurs when conditions are not uniform from pulse to pulse.

AFCRL's primary contribution to ultraviolet absorption spectroscopy has been the development of methods for obtaining rare-gas-continuum light sources of higher intensity and greater stability. One such method is by determination of the best operating pressure to augment the continuum intensity for each rare gas. For example, the helium continuum is best augmented at a pressure of 50 to 55 mm Hg, while the argon continuum is best enhanced at pressures of 150 to 200 mm Hg.

Another important AFCRL contribution was the development of an excitation unit for light sources based on a thyratron-controlled modulator to excite rare-gas continua. The intensities and stabilities realized with this unit have made possible still another development—photoelectric scanning (as against manual scanning of spectral photographs) of the output of the monochromator. Dr. Huffman, in particular, has made significant contributions to photoelectronic scanning.

Most of these contributions were



**Dr. Huffman operates one of AFCRL's vacuum ultraviolet monochromators. The apparatus is used for measuring absorption and ionization cross sections and spectra of atmospheric gases.**

made at AFCRL during the past 10 years. They have led to the new spectroscopic techniques and the more powerful new spectroscopic instrumentation now used in many research laboratories.

*Dr. Robert E. Huffman has been a supervisory research chemist in the Spectroscopic Studies Branch, Aeronomy Laboratory, AFCRL, since 1963. During that time his research interests have centered on vacuum ultraviolet absorption and ionization cross sections, rare-gas continuum light sources, atomic absorption spectroscopy, and spectroscopic instrumentation. He has been with AFCRL and its predecessor organization since 1958 when, as a lieutenant on active duty, he was assigned to the Chemical Physics Branch, Photochemistry Laboratory. There he did research on vacuum ultraviolet cross sections of atmospheric gases and the development of upper-atmosphere chemical release materials.*

*Dr. Huffman has a B. S. in Chemistry (1953) from Texas A & M University and a Ph. D. in Chemistry and Physics (1958) from the California Institute of Technology. In 1967 he accepted a one-year research assignment in the Department of Physics, Imperial College of Science and Technology, London, England. He is a member of the American Physical Society, the Optical Society of America, the American Chemical Society, the Society of the Sigma Xi, and the American Association for the Advancement of Science.*

# weather station in a five-pound package

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

A weather kit completely packaged in a 5 X 8 X 10-inch case, yet capable of performing essentially all the functions of the multiple-operator World War II field weather station, has been developed for use by combat weather teams in Vietnam. The kit, developed by Bernard Weiss of AFCRL, has already been tested in Southeast Asia. The Tactical Air Command has recently ordered 150 of the kits for combat use. They cost about $100 each.

Supplied in the kit are a wind-speed sensor and a wind-direction vane, a barometer, and a wet and dry bulb thermometer for determining dew point and relative humidity. A rain gauge and a clinometer for making cloud-height measurements are also included. In addition to the instruments mentioned, the kit contains several hand calculators, graphs, and conversion tables, plus easy-to-follow instructions for translating observational data into meaningful meteorological values.

**Figure 1. This airman is carrying miniaturized weather equipment which provides him with the capability of taking complete surface-weather and winds-aloft observation. The equipment was designed by Bernard D. Weiss of AFCRL to fulfill Tactical Air Command equipment requirements for weather-support operations in Southeast Asia. The five-pound package referred to in the text is the package hanging from the airman's left shoulder. The contents of this package are shown in Figure 2. The airman is also carrying from his right shoulder a portable miniaturized pilot balloon observational kit which is not mentioned in the text. (See Figure 3 for contents of this kit.) Both kits would enable a combat weather observer to take complete observations in remote areas.**

*Mr. Bernard D. Weiss came to AFCRL in 1962. As a meteorologist in the Equipment Engineering and Evaluation Branch, Aerospace Instrumentation Laboratory, he performs extensive field tests on meteorological equipment to determine equipment accuracy and reliability in an effort to improve meteorological instrumentation, observational techniques, and data-reduction methods. He has served with the Air Weather Service and the Weather Bureau. With the latter, he was stationed in both the arctic and antarctic.*

*Mr. Weiss has a B.S. in Mathematics from the University of Miami, Coral Gables, Florida. He took schooling in meteorology at Chanute Field, Illinois, during his military service. He is a member of the American Meteorological Society.*

**Mr. Weiss exhibits the contents of AFCRL's compact weather kit.**

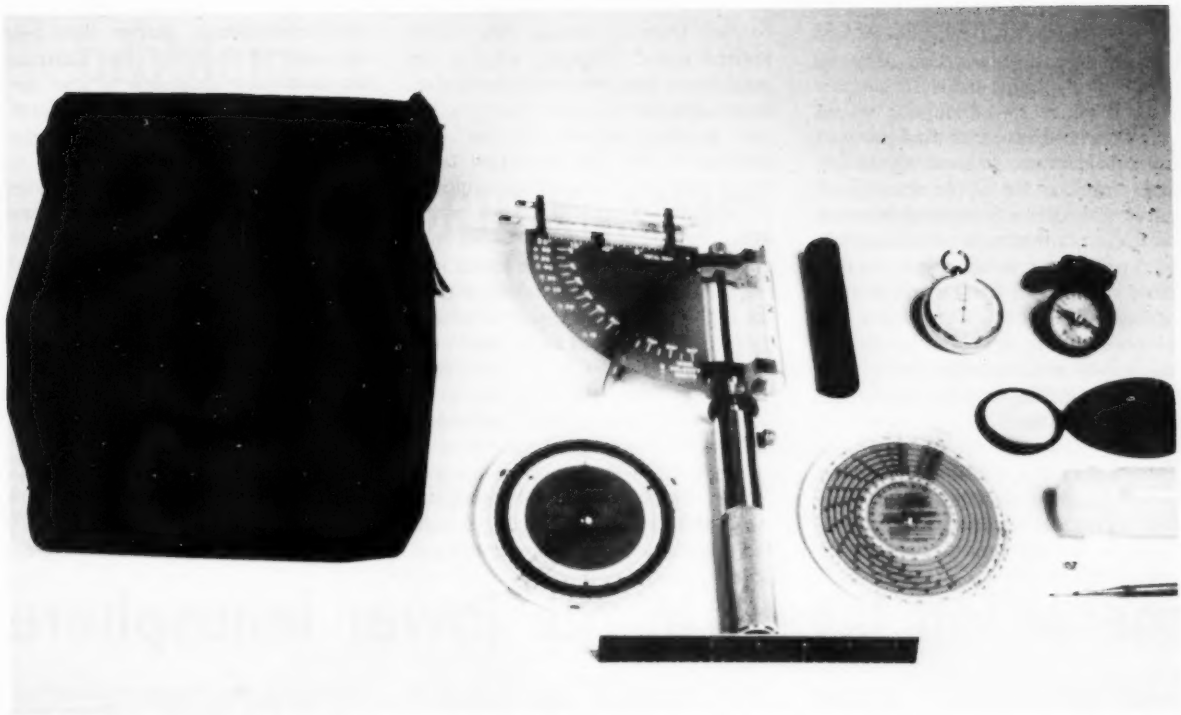


Figure 2. The five-pound package above, mentioned in the text, includes a wind-speed sensor, a wind-direction vane, a barometer, a wet and dry bulb thermometer, a rain gauge, a clinometer, and other useful items.

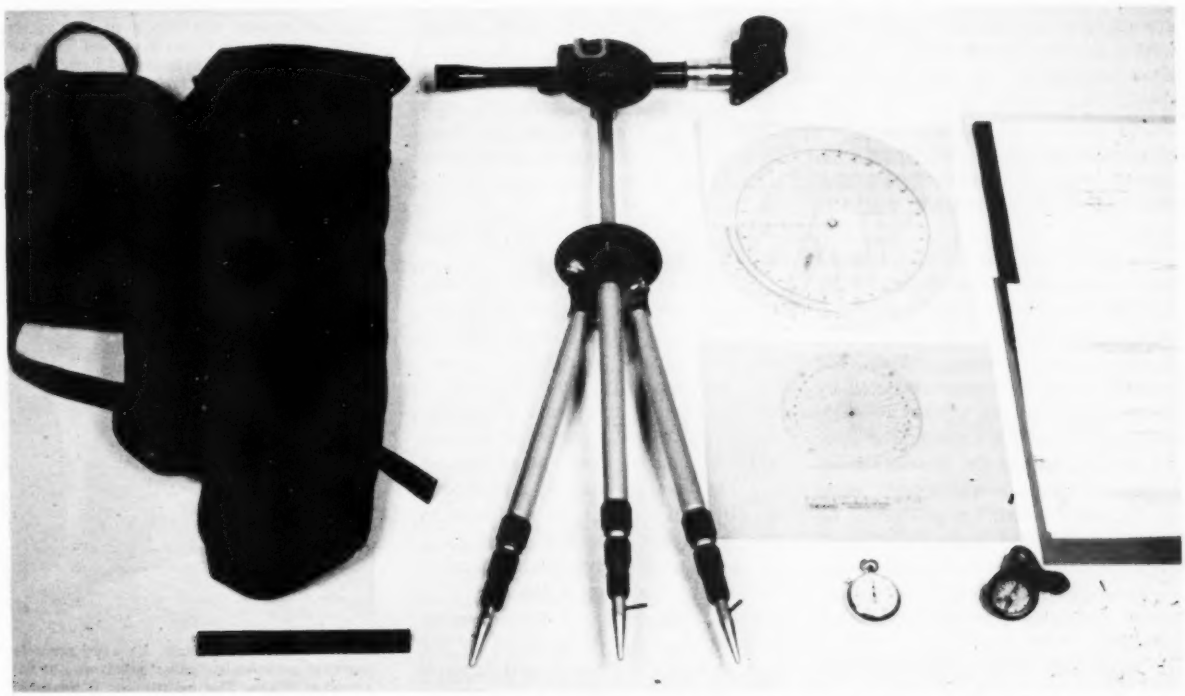


Figure 3. The items above are found in the portable miniaturized pilot balloon observational kit (see Figure 1).The kit includes a theodolite, plotting board, wind speed and direction sensors, thermometer, clinometer, barometer, and 8 cylinders of helium gas.

AERONOMY LABORATORY, AFCRL

# metal ion layers in the lower ionosphere

We would expect to find traces of iron, magnesium, sodium, aluminum, and nickel in the upper atmosphere since meteorites vaporize and these are the elements that meteorites are made of. Further, we would expect to find these elements at the general altitude between 80 and 120 km where the meteorites burn up. And we would also expect these metallic elements to be rather diffusely distributed in an unstructured way.

Our first two assumptions are correct. Our last one is not—at least insofar as those metal elements that have become ionized are concerned. These metal ions tend to concentrate in thin layers of less than 1 kilometer to a few kilometers thick. A certain metal-ion specie may predominate at a preferred altitude stratum. In one particular profile, thin layers of iron ions are centered at 105 km, and silicon ions at 115 km. In addition, a thicker layer containing all the metal-ion species was found at 93 km. The thicker layer at 93 km appears to be a consistent feature of the lower ionosphere, while the other layers vary considerably in magnitude and altitude.

Such structuring is evident in the data from 13 rockets launched by AFCRL from such widely spaced sites as Ft. Churchill, Canada, Eglin AFB, Florida, and Cassino, Brazil. The rocket experiments were designed by Dr. Rocco S. Narcisi of AFCRL who also analyzed and interpreted the data. All rockets carried Dr. Narcisi's cryogenically pumped quadrupole mass spectrometer which has proven to be the most efficient instrument developed to date for obtaining high-resolution data on ionospheric constituents between 60- and 140-km altitude.

In looking at the distributions and concentrations of the metallic ions, two questions arise: First, by what process is the metal element transformed from a neutral state to an ionized state? Second, what is the mechanism that causes the metal ions to concentrate in layers? An obvious—but incorrect—answer to the first question is that the ionization takes place under the vaporization temperatures of the meteorite's entry into the atmosphere. The chemistry of the situation disproves this. While metal ions may, in fact, be produced directly in the high temperatures of atmospheric entry, the metal ions so produced are chemically attacked, capture free electrons, and become neutralized. If we are to explain their persistence and high concentration, we must show a continuously high rate of production.

Dr. Narcisi, in a lengthy analysis, shows that the metal ions are created and maintained by a simple charge-transfer process in which a neutral metal specie picks up an electron from either ionized nitric oxide or molecular oxygen ($NO^+$ or $O_2^+$). The nitric oxide and oxygen then become neutralized. Dr. Narcisi offers experimental evidence of this mechanism. A rocket flight was flown during the annual Leonid meteor shower when there is a great increase in metal species in the upper atmosphere. During the shower there was a marked decrease in $NO^+$ and $O_2^+$ as their charges were transferred to the high-influx metal species.

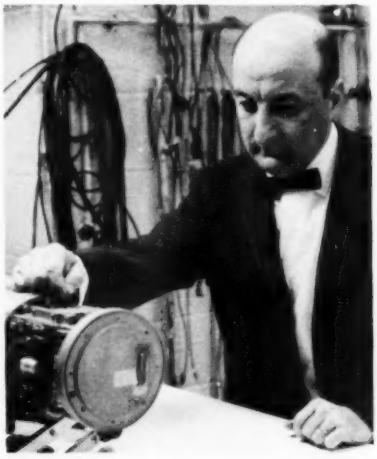
Dr. Narcisi suggests that the separation of metal ions of different types into different altitude strata depends on atmospheric transport processes, the ion chemistry, and the type of meteoroid; for instance, a stony-type meteoroid would vaporize at a higher altitude than an iron-type meteoroid.

The layering may be explained as an effect of ion motions produced by the ionospheric neutral wind field, through a theory developed in detail at AFCRL by Malcolm A. MacLeod. The neutral wind induces a motion in the ions which, being constrained by the geomagnetic field, are forced to move vertically with a velocity component perpendicular to the wind and the geomagnetic field. Since the neutral wind components change sign over distances of 10 to 15 km, alternate increases and decreases of the ion densities result and lead to thin layers. This is the mechanism which creates the dense ionized layers known as Sporadic E. Dr. Narcisi, in previous papers, had carried this hypothesis one step further, suggesting that intense Sporadic E is composed entirely of metallic ions.

*Dr. Rocco S. Narcisi is a supervisory research physicist and Chief of the Composition Branch, Aeronomy Laboratory, AFCRL. He is responsible for conceiving, planning, and directing research to generate new scientific concepts and to contribute to technical knowledge of interest to the Air Force, the Department of Defense, and the National Aeronautics and Space Administration. As a project scientist, he determines the problems to be studied in aerospace composition.*

*Dr. Narcisi received his B.S. in Physics (with honors) from Pennsylvania State University in 1953, his A.M. in Physics from Harvard University in 1955, and his Ph.D. in Nuclear Physics from Harvard in 1959. He was an Air Force lieutenant when he first came to AFCRL.*

*Dr. Narcisi received the Defense Atomic Support Agency Certificate of Service in 1962, and the Air Force Sustained Superior Performance Award in both 1963 and 1964. He is a member of Phi Beta Kappa, Phi Kappa Phi, Sigma Pi Sigma, AAAS, and Sigma Xi (RESA).*



**Dr. Narcisi calibrates a cryogenically pumped positive-ion mass spectrometer for a rocket flight. The instrument is designed to measure positive ions between 60 and 140 km, the D and E regions of the ionosphere.**

# a problem of MAGNETOHYDRODYNAMICS

DR. R. G. POHRER
Directorate of Mathematical Sciences, AFOSR

Professor L. Cesari of the University of Michigan, under a grant from the Mathematics Division, AFOSR, has established a number of existence theorems for solutions of multidimensional Lagrange problems of optimization. These have a wide range of application to problems of scientific and technological interest, in particular to contemporary problems in control theory.

In one of his most recent publications, Professor Cesari applied some of his earlier results to a problem in magnetohydrodynamics. (1) He began with existence theorems for solutions in Sobolev spaces of multidimensional Lagrange problems of optimization in a fixed domain, bounded or unbounded, and applied these previous results to the case where the partial differential equations appear in canonical form. The specific form was proposed by Rashevsky, (2) although Thomas and Titt (3) considered essentially the same form, implicitly.

Lurie (4-6) had discussed necessary conditions for Lagrange problems of optimization with partial differential equations in canonic form, particularly the conditions necessary for an optimal solution in a two-dimensional problem of magnetohydrodynamic channel flow without, however, establishing existence theorems. The establishment of existence theorems for an optimal weak solution for Lurie's problem of magnetohydrodynamics is the unique contribution of Professor Cesari. This solution is weaker than those considered by Lurie, i.e., it is a weak solution in the sense of Gamkrelidze, with state functions in the Sobolev space $W_2^1$.

Similar to Lurie, Professor Cesari considers the rectilinear motion of a conducting fluid along a plane channel of specified width. The specific resistance of the fluid is restricted by two constants which "bound it." The walls of the channel are assumed to be insulated everywhere, except for two sections of equal length occupied by ideally conducting electrodes located opposite each other on different walls. The electrodes are connected through the outer load. As soon as the transverse magnetic field is imposed on the moving fluid, an electric current is induced inside the channel. The total current which flows through the outer wall and the total joule losses are given as certain functionals and, for the case of an homogeneous magnetic field, related by a certain identity. Lurie's problems for the magnetohydrodynamic channel flow are the problems of determining the maximum current and the minimum joule losses. Other analogous problems can of course be taken into consideration, as Lurie himself observed. In the present paper, Professor Cesari proceeded to consider and solve the problem of minimum joule losses.

The interested reader is referred to Professor Cesari's paper for further details.

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# flight around the auroral oval

IONOSPHERIC PHYSICS LABORATORY, AFCRL

In December 1968, AFCRL scientists under the direction of Dr. George J. Gassmann made a circumpolar flight that traced a general path completely around the auroral oval. Not to be confused with the auroral zone, to which it is related, the auroral oval was first shown to exist in about 1960; but its nature was not fully defined until about 1964.

The AFCRL study provided the first complete measurements of the oval. From these measurements, AFCRL hopes to define more precisely the relationships between the earth's magnetosphere, the radio and optical aurora, and the solar effects on both. The visible aurora always occurs instantaneously around the oval circumference.

For the flight, AFCRL's KC-135 flying ionospheric laboratory was used. The KC-135 flew a zigzag path around the oval to obtain data on the spatial extent and intensity of the optical and associated radio aurora. They do not always occur simultaneously.

The research aircraft left L. G. Hanscom Field, Bedford, Mass., on December 12, 1968, and flew to Goose Bay, Labrador, which is near the auroral oval. The next day, December 13th, a zigzag path was followed across Canada to Fairbanks, Alaska. On the 15th and 17th of December, flights were made over the Arctic Ocean, crossing the North Pole each day. On the 19th of December, a direct flight was made from Fairbanks to the vicinity of the North Land and Franz Josef Land island groups of the U.S.S.R. where a zigzag path was followed to Spitsbergen, Norway, and then to Keflavik, Iceland. The following day a route was followed from Keflavik to Goose Bay to close the loop.

The equipments aboard the KC-135 that were used in the measurements were a Granger 3900 ionosounder, a 4-barrel photometer, high- and low-frequency receivers, an all-sky 35-mm camera, and infrared spectrometers.

The auroral oval traces the line along which the outer radiation belt intersects the ionosphere—more specifically, the line is along the outer boundary of this radiation belt. It therefore delineates the structure of the magnetosphere projected onto the polar ionosphere. Along the line of the oval, the ionosphere has direct access to solar particles.

The oval is eccentric with respect to the magnetic pole, with a marked day-night variation. The night side is located at approximately 68 degrees magnetic north, while the day side of the oval is located at approximately 78 degrees. The exact location and width are strongly controlled by magnetic activity. The eccentricity of the oval is closely related to the day-night asymmetry of the magnetosphere which is caused by the pressure and friction of the solar wind. The more familiar auroral zone is now understood as being simply the location of the night part of the oval where intense auroral displays are most frequently seen.

The December 1968 circumpolar flight by AFCRL's KC-135 was the aircraft's second expedition to explore the dimensions of the auroral oval. In 1967, a number of flights were made across a segment of the oval in an area east of Greenland. The results of the earlier flight were recently reported by Jurgen Buchau and Dr. James Whalen of AFCRL, who were also the primary investigators of the recent observational program.

The Air Force is interested in the aurora because of the influence it has on radio communications and navigation and on radar surveillance. AFCRL scientists are seeking a better understanding of the aurora with the ultimate goal of predicting the occurrence and severity of auroral activity.

*Dr. James A. Whalen and Mr. Jurgen Buchau are research physicists with the Ionospheric Radio Physics Branch, Ionospheric Physics Laboratory, AFCRL, where they are investigating the magnetosphere and its interaction with the ionosphere in phenomena such as auroras and airglow.*

*Dr. Whalen has a B.S. in Physics (1950) from Union College, Schenectady, N.Y., and a Ph.D. in Physics (1957) from Washington University, St. Louis, Mo. He came to AFCRL in 1967 from the Accumetrics Corporation where, as Senior Physicist, he planned experiments and designed instruments for measuring the spectra, intensities, and effects of radiation from underground nuclear tests. He is a member of the American Physical Society.*

*Mr. Buchau received his Diploma in Physics from the Albert Ludwig University of Freiburg, Germany, in 1963 and attended the European Space Research Organization's Summer School in Ionospheric Physics, also in 1963. In 1965 and 1966 he took advanced courses in plasma dynamics and wave propagation in plasmas at Northeastern University. Mr. Buchau began working in ionospheric physics in 1959 as an employee of the Deutsche Forschungsgesellschaft at the Ionospheric Institute of the Deutsche Bundespost, Breisach, Germany. His experience has included a variety of assignments, primarily in radio-wave propagation research.*

Dr. Whalen (left) and Mr. Buchau examine photometer data gathered on their flight aboard the KC-135 around the auroral oval.

# radio emissions provide clear clues to solar proton events

IONOSPHERIC PHYSICS LABORATORY, AFCRL

Radio astronomers at AFCRL have uncovered clues for predicting the onset of major solar proton showers with a reliability far exceeding that previously possible. With the AFCRL prediction criteria, the false-alarm rate (the prediction of events that do not occur), and the "miss" rate (a proton shower not forecast), have been reduced to a level approaching assurance—approaching, but not quite reached.

Of the huge bursts of energy and matter that erupt from the sun during a solar flare, high-energy protons have the most serious terrestrial effect. When high-energy protons reach the earth's atmosphere (they are guided toward the poles by the earth's magnetic field), they create a condition known as polar-cap absorption (PCA)—or radio blackout. This condition profoundly degrades the performance of Air Force communications, navigation, surveillance, and detection systems. For manned space vehicles caught in the proton shower, there is an ionizing hazard to both passengers and electronic equipments.

Because of these effects, the forecasting of solar proton events is a high-priority goal of both radio and optical solar astronomers. The approach to forecasting used by radio astronomers differs from that of optical astronomers. The optical astronomer looks for prediction clues in the size, configuration, age, and growth rate of sunspots and their associated magnetic fields. He hopes to predict the occurrence of solar proton showers at least seven days in advance—and has a long-range goal of predicting showers a month or so in advance.

The prediction methods of the radio astronomer, however, are quite different, and lead to short-term prediction—3 minutes to about 14 hours in advance of their terrestrial influences. The AFCRL radio prediction scheme is based largely on the analysis of the spectral characteristics of the radio bursts associated with a solar flare.

For background, it should be noted that almost all solar flares are associated with sunspots, and all proton showers are associated with solar flares. But not all sunspots generate solar flares, and not all solar flares produce proton showers. Proton-producing flares are, in fact, only a small percentage of all flares. During the quiet sun years of the 11-year solar cycle, we may find no major proton events during a given year. During the active period of the solar cycle (the peak of which was reached this year), as many as 8 or more may occur. Thus, we may consider the long-term yearly average of such showers to be about 4.

AFCRL's radio spectral prediction method was worked out by John P. Castelli and his colleagues. AFCRL is well equipped to obtain spectral plots of radio emissions. At its Sagamore Hill Radio Observatory in Hamilton, Mass., radio telescopes monitor solar radio energy at 200, 606, 1415, 2695, 8800, and 15,400 MHz. (Figure 1 shows some of the antennas in use.) Within this range of frequencies occurs the spectral pattern critical to the identification of proton showers.

Radio emissions from flares vary widely; but proton-producing flares have a clear spectral signature. When signal amplitude (or flux) as a function of frequency is plotted, we find a distinct U-shaped spectrum. The key feature of the spectrum is a null, or a minimum flux, usually at frequencies between 600 and 1000 MHz. Thus, the plot shows a strong signal at about 200 MHz, then a decrease in relative strength in the 600- to 1000-MHz range, followed by an increase in strength.

In addition to the U-shaped spectrum, Castelli's prediction criteria call for a radio burst signal exceeding 1000 flux units (a measure of amplitude or signal strength). The radio burst itself must be of the type known as Type-IV radio emission. Type-IV radio emission occurs during the flare eruption across all frequencies within a time span of a few minutes. The magnitude of the flare, itself, as observed visually with optical telescopes, has been found to be a secondary criterion—and may actually lead to a high false-alarm rate if given undue weight in the ordering of prediction criteria.

Castelli examines possible models that might explain how the U-shaped radio spectrum is produced. A model suggested in 1963 by Wild and others postulates that the flare shock wave produces two distinct radio emissions. One is synchrotron radiation resulting from the acceleration of electrons in the region just above the chromosphere (15,000 km above the visible disk of the sun) to produce large radio fluxes at the higher frequencies. The second radiation source, producing emissions at the lower frequencies, results from the excitation of plasma radiation farther out in the corona (more than 1,000,000 km from the visible disk). Between these two radio-energy-generating mechanisms, we have a distinct null resulting in the U-shaped spectrum.

**Figure 1. Some of the antennas used by AFCRL to monitor the sun for unusual radio emissions which might provide clues for forecasting solar effects on the terrestrial environment.**

*Mr. John P. Castelli, a supervisory research electronics engineer and Chief of the Solar Section, Radio Astronomy Branch, Ionospheric Physics Laboratory, AFCRL, is in charge of solar radio work within the Branch. His responsibilities include the establishment and maintenance at Sagamore Hill, Hamilton, Mass., of a solar radio facility for making continuous observations of the microwave radio sun at multiple wavelengths between 1 cm and 1 m. He oversees technical and scientific aspects of the solar program, including system design and data evaluation and reporting. In addition, he plans and leads solar-eclipse projects, monitors contracts related to in-house solar work, and assists and advises the Air Weather Service in its Space Weather Forecast mission.*

*Mr. Castelli received his A.B. (cum laude) in 1938 and his M.A. in 1939, both from Boston College, Newton, Mass. From 1943 to 1946 he served with the Air Force as a radar officer, from 1946 to 1949 he worked on instrumentation for the V-2 and Aerobee rockets, and from 1949 to 1955 he was engaged in ionospheric research.*

# AN IONOSPHERIC EVENT OBSERVED BETWEEN 12:11 AND 12:18 P.M. ON 2 FEBRUARY 1967

Let us go back to a single instant of time—to 12:11 p.m. EST on February 2, 1967. What we want to see at this frozen moment is a vertical cross section of the ionosphere. If we permit ourselves certain enhancement, filtering, and smoothing techniques so that we may isolate our subject for clear observation, then we can see that electrons in the ionosphere have tended to concentrate along a broad horizontal plane. This horizontal layer stretches from Massachusetts to Illinois and northward into Canada—maybe farther, but our view is limited.

The layer of electrons is not exactly horizontal. It tilts upward about 10 degrees toward the north. Nor is it flat; it is gently rolling. Now let's slowly release this moment and see what happens. The layer of electrons moves downward, and fading into view is a layer of minimum electron concentration. If we set our controls on real time, then we see that the alternating strata of concentration and depletion are moving downward with the speed of sound—about 700 meters per second at 200 km. In less than a minute, another layer of maximum concentration has come into view, to be followed in sinusoidal fashion by a minimum. Even though the difference between maxima and minima is only 2 percent, the waves are clearly visible. If we watch until about 12:18 p.m., then we will see eight such alternating strata moving downward at acoustic velocities. There may have been more but, by that time, the satellite which illuminated our view has moved out of range.

What we have seen is an unusual vertically traveling ionospheric disturbance, first observed by John A. Klobuchar of AFCRL, N. Narayana Rao of the University of Illinois, and G. F. Lyon of the University of Western Ontario. They didn't directly observe it, of course. They painstakingly deduced that it happened using radio observations from receivers at Hamilton, Massachusetts, Danville, Illinois, and London, Ontario.

The observation of traveling waves as such in the ionosphere is not unusual. The ionosphere is in a constant state of restless, undulating motion—much like the ocean—and it is easily disturbed. A missile passing through it sets off a horizontal wave train that can be detected hundreds of miles away, and an atomic explosion can send ionospheric waves completely around the world.

What made the observation of the vertically traveling acoustic wave of particular interest was the fact that the vertical plane wave was of such vast geographical extent, that the wave was traveling at acoustic velocities, and that it had an extremely short period—less than a minute. The peri-

**Mr. Klobuchar examines total electron content record from the NASA ATS-3 geostationary satellite.**

ods of traveling ionospheric waves are usually measured in tens of minutes or in hours.

The characteristics of the wave were deduced from data simultaneously taken at the 3 receiving sites. All sites recorded the Faraday rotation of signals from the radio beacon satellite, BE-B, which was in a 1000-km orbit transmitting at 40 and 41 MHz. Faraday rotation of the plane of polarization of the signal gave the values for the total electron content of the ionosphere. If we can measure the total electron content of the ionosphere, then rhythmic fluctuations in electron concentrations can be interpreted as a traveling wave.

When one is assured that one has observed an unusual occurrence, the next step is to try to explain it, to look for causes. Was there an unusual solar event or condition at the time of the observation? A sudden magnetic disturbance? The three scientists found that the sun had been quiet for several days prior to the event, and that there had been no marked magnetic disturbances. Surface weather activity was also checked. A cold front and a warm front had joined at the time of the observation in the area of Hamilton, Mass. There could be a causal connection between the frontal systems and the vertical wave—but how the coupling could work is uncertain.

The three scientists did conclude, however, that the source was probably above the ionosphere. Such a source must be one that could cause the atmosphere over a broad geographical expanse to oscillate like a weight on a spring. No mechanism that could cause this has come to mind.

*Mr. John A. Klobuchar is a general physical scientist in the Radio Astronomy Branch, Ionospheric Physics Laboratory, AFCRL. He is currently responsible for measuring F-region total electron content as part of a program to determine ionospheric effects upon v-h-f radio waves from satellites and celestial sources, and has developed new receiving techniques for measuring polarization.*

*Mr. Klobuchar has a B.S.E.E. (1958) and an M.S. (1960) from the University of Illinois. He came to AFCRL in 1960 as an Air Force lieutenant and continued his work there as a civilian after his release from active duty in 1963. He has published several papers on F-region electron content effects and is pursuing further studies in this field using data from stations in a worldwide Joint Satellite Studies Group network. He is a member of the Institute of Electrical and Electronic Engineers, the American Geophysical Union, the Research Society of America, and the American Association for the Advancement of Science.*

# planning for national information systems

ROWENA W. SWANSON, Directorate of Information Sciences, AFOSR

AFOSR was recently privileged to accept as a final report a document that should become a landmark in the field of information-systems development. It is a *Study of Scientific and Technical Data Activities in the United States*, produced by Science Communication, Inc. (SCI), under ARPA sponsorship and monitored by the Directorate of Information Sciences, AFOSR. (1)

The *Study* has roots in the explosive growth of the scientific and technical literature over the last three decades. The Federal Government has only recently begun to provide a measure of direction over storage and retrieval activities that have proliferated in an attempt to cope with the explosion. In 1962, the Federal Council for Science and Technology established a Committee on Scientific and Technical Information (COSATI). Figure 1, showing the COSATI organization, reflects the complex involvement of a large number of Federal agencies with information-handling problems. As an aid to studying and trying to resolve many pressing storage and retrieval problems, COSATI formed the Panels and Task Groups shown in Figure 1. SCI's Study is one of the investigations called for by the Task Group on National System(s) for Scientific and Technical Information.

The *Study* is a monumental compilation and analysis. It is in 3 volumes that total approximately 1,200 pages. *Volume I* provides the factual and analytic bases for a plan for the development of a national program for handling scientific and technical data. *Volume II* is in 3 parts. *Part A* describes the data activities in 10 selected fields of science and technology:

Aerospace Science and technology
Electronics and Electrical Engineering
Materials Science and Engineering
Chemistry and Chemical Engineering
Agriculture and Food Technology
Biomedical Sciences
Pharmacology
Social and Behavioral Sciences
Environmental Science and Geosciences
Oceanography

Each of the descriptions presents the characteristics of the data, data-flow patterns, formal procedures that now exist for handling the data, and representative data-related problems particular to the field. (See Figure 2, for example, which pictures information exchange in the R & D electronics environment oriented to the production of components.) *Part B* reviews the data-handling and information-flow patterns that have arisen within several special-interest communities. It covers those of medical school and related research institutions; professional societies and trade

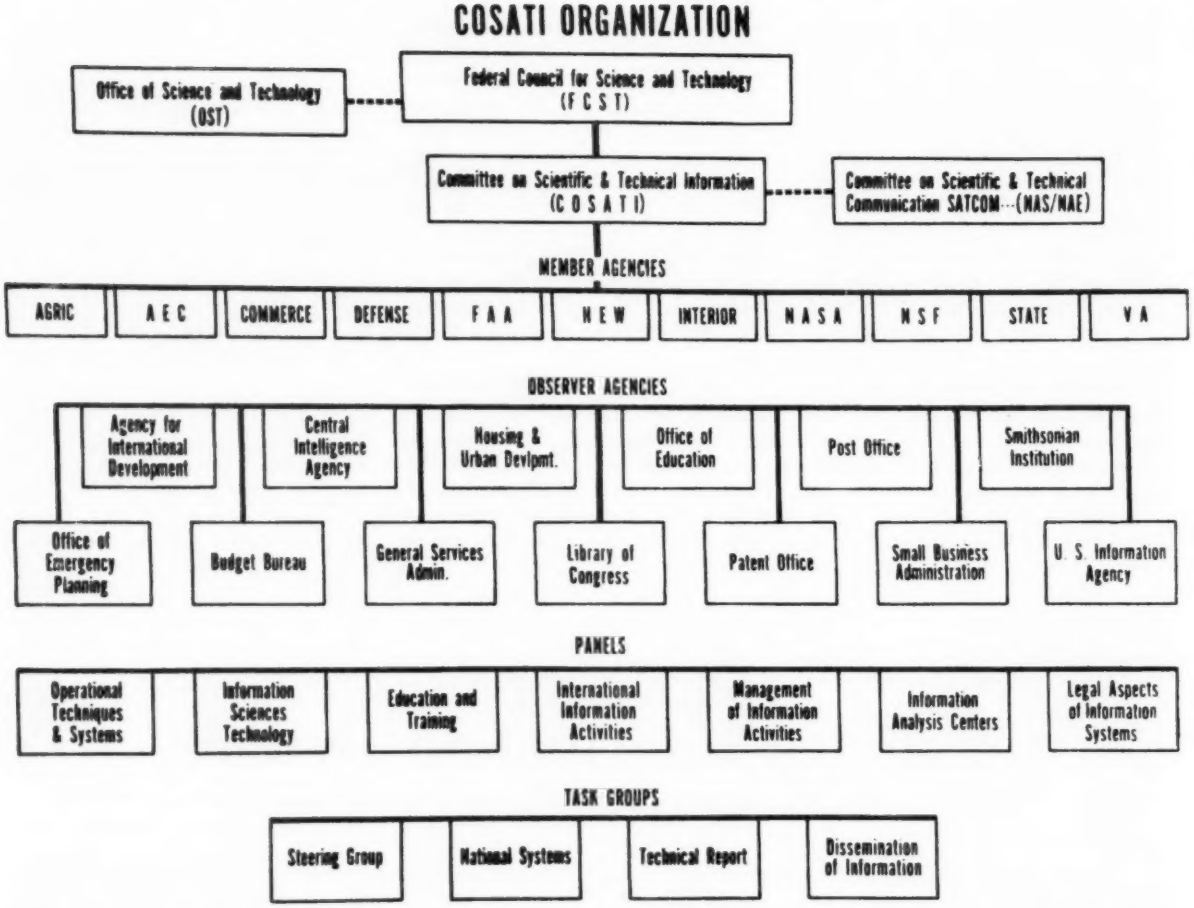



**Figure 1. COSATI Organization Chart. Reproduced in the SCI *Study* from *Progress of the United States Government in Scientific and Technical Communication*, Executive Office of the President, Federal Council for Science and Technology, 1966.**

associations; and commercial data centers. *Part B* also assesses the capabilities of current equipment for use in information systems of national scope. *Part C*, bound as a separate volume, is an in-depth census of 266 centers and service operations that are considered by SCI to be potentially amenable to coordination at the national level.

The conclusions in *Volume I* are significant because they summarize the assessments of approximately 300 experts who were asked to comment on about 100 major issues identified as relevant by SCI. In over-all perspective, SCI has found that "existing organizational structures and human competencies are over-extended in terms of their abilities to effectively accommodate evolving data-management and data-handling needs. In addition, alleviation of this situation does not appear imminent, for only now are the individuals and organizations affected beginning to recognize the gravity of the situation. To date, attempts to improve data-management and data-handling operations have been rendered largely ineffectual due to crisis-type actions and piecemeal approaches to broad problems. Significant improvements cannot be expected until needs are better defined, organizational responsibilities are identified and accepted, and increased funds are made available to support the effort required to alleviate existing problems."

Principal factors that pose difficulties in the development of information systems are concerned with personnel, finances, equipment, administration, input data, and coordination. The need for both systems- and subject-oriented personnel appears one of the most crucial. People are needed who combine talents of both types. Adequate training programs, both stop-gap and long-range, have yet to be developed. High costs of equipment, computer services, and space for housing computer facilities are compounded by current budget squeezes. Opinions differ on future sources of funds, some suggesting the Federal government, others state governments or service users. The unreliability of computer equipment for continuous on-line operations has necessitated backup systems and discouraged some experimentation. Few simple interpretive programs

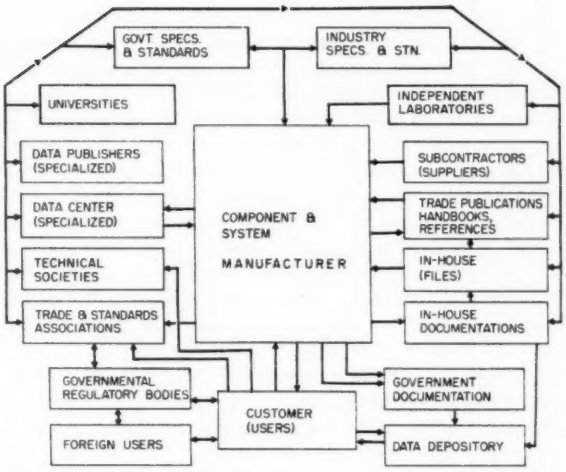



**Figure 2. Information-Flow Environment in R & D Communities.**

and languages exist that can be easily learned by users, thereby also slowing experimentation and direct interaction by nonprogrammer users and systems personnel. Few program and hardware configurations exist that enable a remote user, at his discretion, to work with files in a batch or computing mode or in conversational interaction. Many users need the capability of being able to work with a large variety of analog data, and of being able to obtain transformations from analog to digital form. Many administrators who control budgets are not well informed on the value of systems and cost and personnel requirements. Many users are critical of the quality of the data in the systems. Lack of coordination of systems, sometimes even within a given institution, has produced duplication of effort, gaps in coverage, confusion to users, and skepticism that the morass can be resolved.

Nevertheless, the SCI *Study* finds that operational information systems and networks are practical possibilities. The *Study* predicts that "Radical changes in data-handling systems probably will not occur quickly simply because system designers do not know precisely the data service needs of scientists and technologists. In addition, even when service requirements are well defined, the system designer does not yet know how to effectively match data-handling equipments and methods to data service requirements. Quite likely, new data-handling systems will be introduced in an evolutionary fashion with the computer first used as an aid for structuring, storing and formatting data for distribution in conventional forms. Knowledge gained from such experience will then be applied to the implementation of more highly automated systems, including query-processing capabilities. Similarly, computer techniques which are already widely used in design and other data-manipulation operations at the work station of the scientist or technologist will continue to be refined and expanded in application. Therefore, it does not appear unreasonable to anticipate a future merger of data-handling systems to serve all of the scientist's or technologist's data-handling needs, both archival and day-to-day manipulation. At least this possibility provides a future frame of reference which possibly can guide data-handling system-development efforts."

The SCI *Study* proposes a 4-phase plan for implementation over a six-year period (see Figure 3). The plan is consonant with COSATI's recognition that there should be

| PHASE DESIGNATION | PHASE I | PHASE II | PHASE III | PHASE IV |
|---|---|---|---|---|
| PROGRAM ELEMENT | PLANNING: NATIONAL DATA PROGRAM DEFINITION | PLANNING: NATIONAL DATA SYSTEM(s) CONCEPT DEFINITION | IMPLEMENTATION: NATIONAL DATA SYSTEM DEVELOPMENT | IMPLEMENTATION: NATIONAL DATA SYSTEM OPERATION |
| TIME SEQUENCE | 1 YEAR | 2 YEARS | 3 YEARS | CONTINUOUS |
| RELATIVE LEVEL of EFFORT by FUNCTION | | | | |
| CENTRALIZED PROGRAMMING | 1 | >1 | 1 | <1 |
| PLANNING & COORDINATION | 2 | 20 | 60 | 20 |
| IMPLEMENTING & OPERATING | 0 | 10 | 100 | >500 |

° Arbitrarily designated as 1

**Figure 3. Phases of SCI's Proposed National Data Program Plan.**

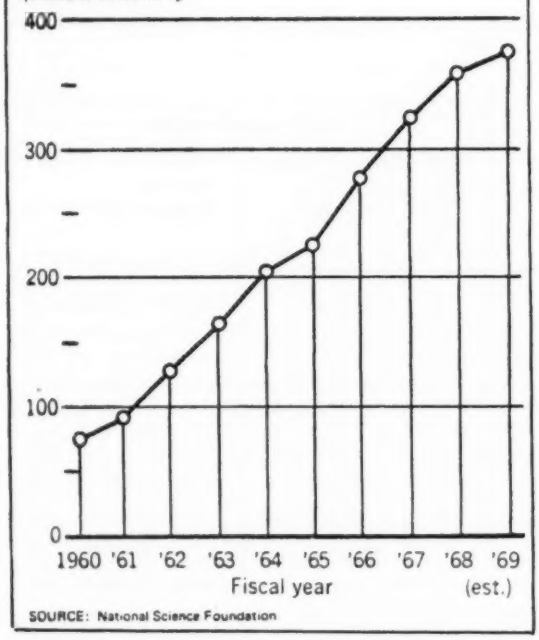
no disruption of existing information operations, and that account be taken of the widely differing capabilities of existing systems and realities of funding, long-established practices, rapid changes in information technology, and differing needs of the various segments of the user communities. Moreover, the Government can only encourage, not direct, private activities, to join in a national undertaking. The plan is called a "preliminary blueprint" for establishing a National Scientific and Technical Data Program.

Under the plan, SCI envisions a one-year Phase I for organization that would include the formation of a Scientific Data Program Office in the National Science Foundation, a Technical Data Program Office in the Department of Commerce, a Data Systems Technical Information Center to support the program, and a National Advisory Council for Scientific and Technical Data whose panels would provide input for the program plan. A two-year Phase II is specified for critically reviewing the requirements for data-management and data-handling systems at local and national levels, and for conducting development and prototype tests to determine the adequacy of equipment and methods for meeting management and handling requirements. A three-year Phase III contemplates the development and testing of methods and facilities for serving the data-handling needs of specific communities. It anticipates that several systems will be under development concurrently, and will differ substantially as to structure and function, some being centralized and others decentralized, depending on the needs of the community to be served. Standardization efforts are expected during this period so that the various systems can be compatible. Though this development phase is expected to be evolutionary for specific scientific and technical communities, increasing integration within Federal agencies is foreseen for general-purpose data collection. The operational Phase IV should increasingly involve non-Government organizations which are expected to participate in the program voluntarily.

Whether or not SCI's plan is adopted in part or in

Chart 21

**Trends in Federal obligations for scientific and technical information activities**




SOURCE: National Science Foundation

Figure 4.

TABLE 22. FEDERAL OBLIGATIONS FOR SCIENTIFIC AND TECHNICAL INFORMATION, BY AGENCY, FY 1968 (EST.)

(Millions of dollars)

| | Total obligations | Percent share |
|---|---|---|
| Total, all agencies | $357 | 100.0 |
| Department of Defense | $143 | 40.0 |
| Department of the Army | 75 | 20.9 |
| Department of the Navy | 17 | 4.8 |
| Department of the Air Force | 23 | 6.3 |
| Defense Agencies | 28 | 8.0 |
| Department of Health, Education, and Welfare | 73 | 20.5 |
| Food and Drug Administration | 5 | 1.3 |
| Office of Education | 10 | 2.8 |
| Public Health Service | 58 | 16.3 |
| National Institutes of Health | (20) | (5.6) |
| National Institute of Mental Health | (6) | (1.7) |
| National Library of Medicine | (28) | (7.7) |
| Department of Commerce | 49 | (13.6) |
| National Bureau of Standards | 8 | 2.3 |
| Patent Office | 37 | 10.5 |
| Other subdivisions | 4 | 0.8 |
| National Aeronautics and Space Administration | 25 | 6.9 |
| Library of Congress | 18 | 5.1 |
| National Science Foundation | 15 | 4.3 |
| Department of the Interior | 14 | 4.0 |
| Geological Survey | 7 | 1.9 |
| Other subdivisions | 7 | 2.1 |
| Department of Agriculture | 9 | 2.4 |
| National Agricultural Library | 3 | 1.0 |
| Other subdivisions | 6 | 1.4 |
| Atomic Energy Commission | 5 | 1.3 |
| Other agencies | 6 | 1.9 |

NOTE: Detail may not add to totals because of rounding.

Figure 5.

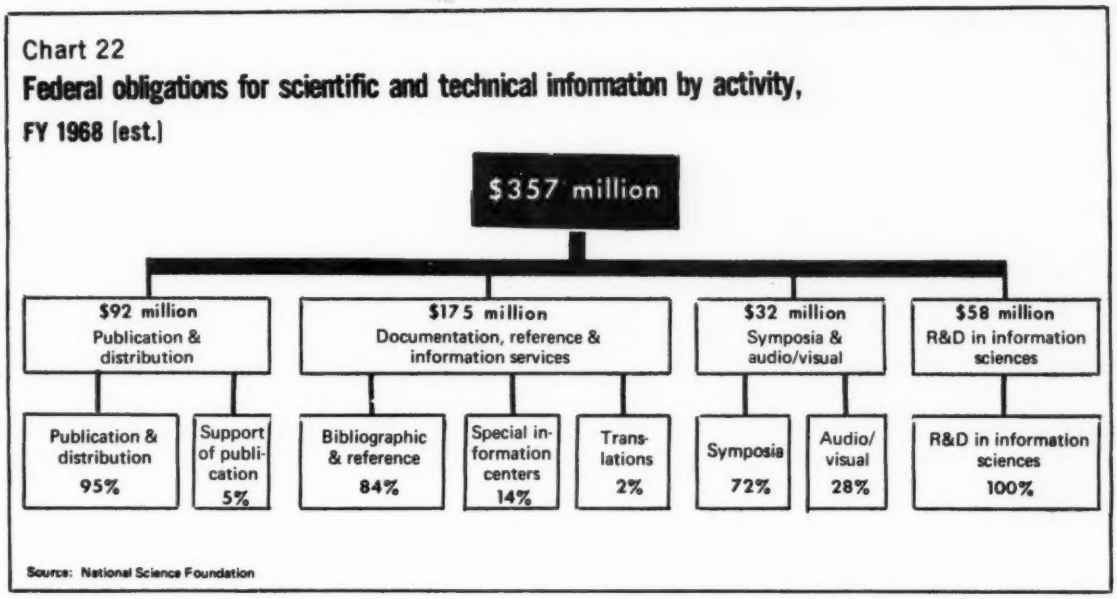



**Figure 6.**

whole, the factual portion of its survey should be highly beneficial to all individuals and groups concerned with any aspect of information-system design, operation, or use. This author concurs with SCI's conclusions, considers them factual, and believes that SCI's recommendations are realistic.

Information has been called a national and international resource by a U.S. Senate Committee, and by others. (2) It is a commodity that is expensive for private and public groups to produce. It has become an expensive commodity to package for use. (3) It has many different forms, and is needed in many different ways by many different people—and now, also, by many different machine-based systems. Sound methods of handling information for the various people and purposes it ought to serve are urgently needed and critical for the effective functioning of military, scientific, industrial, and social organizations. The all-pervasive nature of the commodity and the need, and the long-term deficit spending required for integrated program development, make the Federal Government the focal point for the national effort, and impose pressure on the Government to establish and put a broad-scope plan into operation.

It seems inevitable that some version of the SCI projections will begin to be implemented during the next few years. Ultimate return on total investment will depend on realistic provisions for people, time, and money, and on understanding cooperation among all the participants, throughout the development of the program.

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(3) Almost three years ago, the Federal Government was spending over $2 billion per year to acquire and operate data-processing equipment. A June 1966 White House Memorandum reported that the Government was using 2,600 computers and employing 71,000 people in data-processing work. *Data Processing Management in the Federal Government,* Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, 90th Cong., 1st Sess., July 1967, p. 27. The SCI *Study* notes that the input load at NASA's Goddard Space Flight Center averaged 237 million data bits per day in 1967, a volume almost twice that for 1966. The magnitude of information activities is evident from Figures 4, 5, and 6, which are contained in NSF's latest report in the series: *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1967, 1968, and 1969,* Vol. XVII, Washington, D.C.: National Science Foundation, August 1968. Rept. No. NSF 68-27, at pages 59, 60, 64.

# Q-machine plasma research

JOHN C. CORBIN, JR.
Plasma Physics Research Laboratory, ARL

If a plasma physicist were asked what kind of plasma he would like to have in which to conduct his experiments, he would choose a plasma that was uniform in density and temperature and free of electric fields and currents.

In 1959 the idea of creating a fully ionized plasma utilizing the principle of contact ionization of cesium on hot tungsten was conceived, and a description of the first device, designated as "Q-machine," was published in 1960 by Rynn and D'Angelo.(1) Because the plasma is generated by a purely thermal process without any externally applied electric field, it was thought that the generated plasma would be quiescent (hence the name Q-machine), meaning that it would not exhibit undesirable oscillations and instabilities. Since that time a profusion of Q-machines has been designed and built in more than 25 Government, university, and industrial research laboratories throughout the world.

The principle of operation of each of these devices is relatively simple and substantially the same. An alkali or alkaline earth metal (cesium, potassium, sodium, barium) is heated in an oven, and a neutral beam of the metal vapor is injected under pressure onto a hot plate (tungsten, tantalum, rhenium) heated by electron bombardment to a sufficiently high temperature to emit electrons. The electrons, together with the ionized metal vapor, create a fully ionized plasma. The plasma is contained under vacuum in a cooled cylindrical chamber between two plates by an axial magnetic field set up by solenoids concentric with and along the entire length of the chamber (Figure 1). Another oven. injector, and hot plate are often used

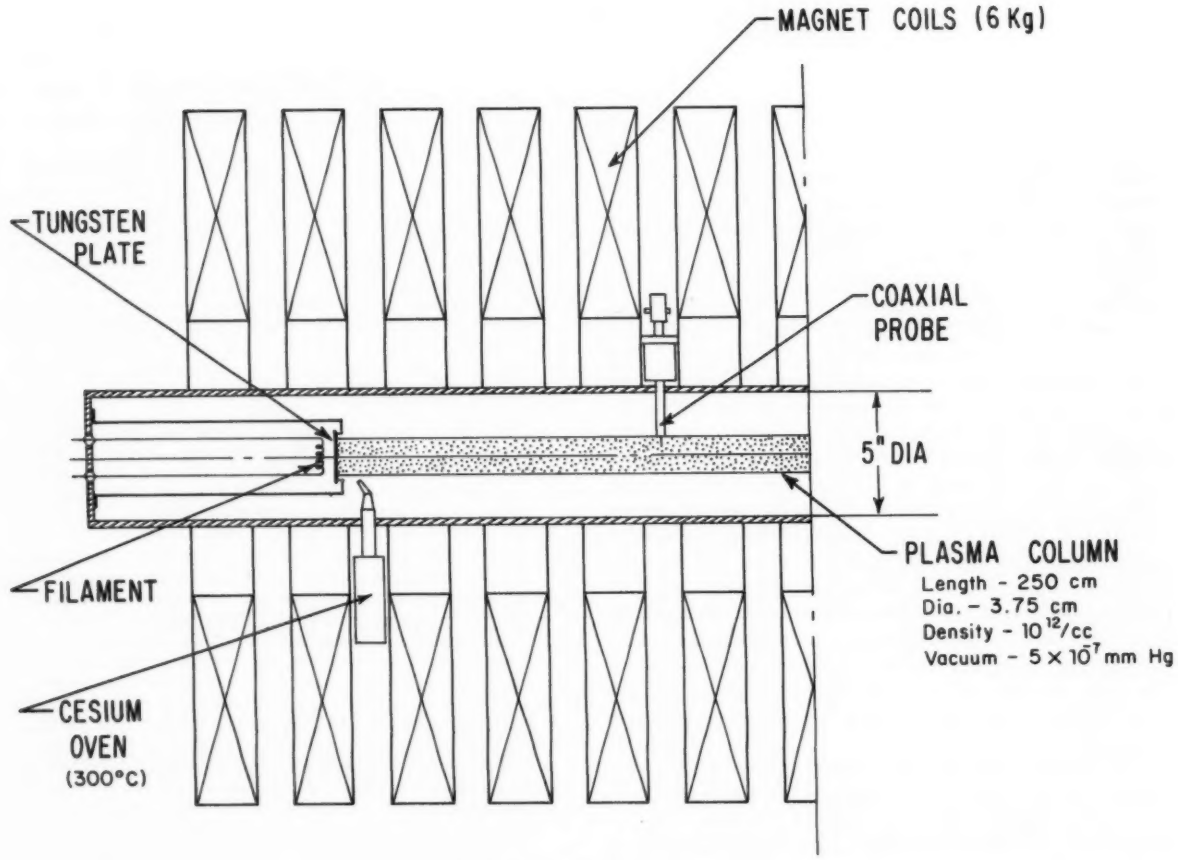


**Figure 1. Large Q-machine device.**

at the opposite end of the chamber to reduce plasma losses.

Very soon after the first device was built, experimenters discovered that life (nature) was not as simple as they would have liked. In 1962 D'Angelo and Motley (2) observed low-frequency oscillations (10-30 KHz) in a potassium plasma operated single ended (with only one hot plate) when the temperature of the hot plate was kept low enough so that there was an insufficient emission of electrons from the plate to neutralize the total ion flux produced by surface ionization. Because of the excess of ions, a positive ion sheath was formed at the surface of the hot plate. In 1963 Lashinsky (3) observed and identified low-frequency oscillations in a cesium plasma operated double ended (with two hot end plates) as normal modes of the universal drift-wave instability theoretically characteristic of a weakly inhomogeneous, fully ionized plasma confined by a strong magnetic field. In contrast with other instabilities, the universal instability does not require an external driving force such as current flow along the magnetic field, but can develop simply because a density gradient exists in a quiescent isothermal plasma located in a uniform magnetic field. In a Q-machine the plasma density is high along the column axis, but falls off rapidly at the edge of the column. Thus, a density gradient exists which can excite low-frequency drift waves in the azimuthal direction.

Lashinsky further observed that, for single-ended operation and plasma densities less than $7 \times 10^{10}$ cm$^{-3}$, the universal instability was stabilized by ion Landau damping in a plasma whose dimensions satisfy a length-to-radius criterion of $L/R \leq 10$. He also observed "mode jumping," a nonlinear transfer of energy from lower damped modes to higher undamped modes, and "mode locking," a nonlinear mode interaction whereby frequencies of the higher modes remain integral multiples of the lowest mode with changes in the wave number brought about by changing the length of the plasma column.

In a potassium plasma operated double-ended Buchel'nikova (4) observed an instability with a fundamental oscillation of 60-70 KHz when the Larmor radius of the ions is comparable with system dimensions. She also observed that, in this case, the diffusion coefficient is much greater in magnitude than the classical value and exhibits only a weak dependence on magnetic field. In the region where the instability is damped (densities $>10^{10}$ cm$^{-3}$), the diffusion coefficient is close to the classical diffusion coefficient in absolute value, and is dependent on magnetic field.

As additional experience was gained by researchers using Q-machines of various configurations and operating parameters, it became apparent that boundary conditions play a significant role in the physical processes that are observed in the plasma column. In 1966 Chen (5) pointed out important effects that could occur if temperature gradients existed on the hot end plates. He showed that temperature gradients can affect density and potential distributions, radial drifts (and therefore diffusion measurements), drift-wave velocities, and can possibly excite other instabilities. Small temperature nonuniformities on the hot end plates can produce d-c electric fields in the plasma which, in turn, can cause plasma drift to the chamber walls.

In 1968 Hendel, Chu, and Politzer (6) pointed out that, in their machine, the radial temperature distribution of the end plates is essentially uniform in the center and nonuniform near the edges. This strong radial temperature gradient is responsible for setting up strong radial electric fields in the plasma which produce "edge oscillations" and other effects which are difficult to sort out and analyze. For this reason they purposely collimated their neutral particle beam to produce a large density gradient near the center of the column, where the temperature is uniform, and made the density gradient at the outer edge of the column as small as possible. They concentrated their work on explaining physical processes occurring in the inner region, where the effect of the density gradient is dominant. They observed a density-gradient-driven collisional drift wave which produced plasma losses one order of magnitude greater than that predicted by classical theory. More recently they identified density-gradient-driven drift waves in the collisionless regime (number density $<10^{9}$ cm$^{-3}$) where several independent unstable modes are observed simultaneously rather than a single dominant mode.

A number of approaches have been explored to suppress these drift-wave instabilities. Hartman and Munger (7) placed a current-carrying rod along the axis of the column which adds an azimuthal magnetic field to the confining axial field. This "magnetic shear" was effective in damping higher-order modes under certain conditions. Chen and Mosher (8) also observed that application of magnetic shear dramatically reduces d-c convective losses.

Very recently Chen and Rogers (9) showed that, if an aperture is located close to the hot plate and a small voltage is applied to the aperture, there is a range of voltage (roughly 0-2 volts) over which the plasma is quiescent and no oscillations in the plasma are observed.

These are only a few of the many experiments that have been performed by researchers on the various Q-machines. However, they are representative of the time and effort that have been expended to gain an understanding of the physical processes occurring in plasmas under relatively well-controlled conditions.

The latest research findings will be presented at the Second International Conference on the Physics of Quiescent Plasmas to be held in Paris in September 1969. Major topics of the Conference will be the propagation of waves and instabilities, diffusion across a magnetic field, recombination phenomena, nonlinear effects, diagnostic techniques in alkali plasmas, and the production of quiescent plasmas.

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*Mr. John C. Corbin, Jr., Deputy Director of the Plasma Physics Research Laboratory, ARL, has a B.E.E. from Cornell University (1950), and an M.S.E.E. from the Ohio State University (1963). He has done predoctoral work at Ohio State and has attended a summer institute in plasma physics at Princeton University. After joining ARL in 1959, Mr. Corbin served successively in the Research Operations Office and the Plans and Analysis Office. He has been assigned to the Plasma Physics Research Laboratory since 1964.*

*Mr. Corbin is a registered professional engineer in Ohio, and is Director of the Dayton Chapter, Group on Engineering Management, IEEE. He is also a member of the American Physical Society and two national engineering honor societies, Tau Beta Pi and Eta Kappa Nu.*

*As Deputy Director of the Laboratory, Mr. Corbin assists in the management and technical direction of the research program in plasma physics in which fundamental studies are made to determine the characteristics and properties of plasmas as a necessary part in the evolution of new and novel plasma-based devices for Air Force application. He has a number of publications to his credit.*

# THE APPLICATION OF CONTROL THEORY TO PHYSIOLOGICAL SYSTEMS

CAPT A.D. DAYTON
Directorate of Mathematical Sciences
AFOSR

Over the past 20 years there has been an ever-increasing use of mathematical principles and theory in the areas of clinical practice and research in the medical and life sciences. The first major successes in this area involved the development and use of significantly improved models for a variety of clinical and research purposes. This was followed by the further development of prosthetic devices of many kinds, including artificial organs, and by the application of digital and analog computers to a host of clinical and research problems. In the latter category, one sees the growing use of computers for the analysis of brain waves, electrocardiograms, etc. More recently, there has been a growing interest in the use of the concepts and theory of control to build quantitative mathematical models of the many control and regulatory processes present in all animals (including man) and to achieve thereby a greatly improved understanding of these processes. This interest on the part of mathematicians, engineers, and medical and life scientists is quite apparent from the recent publication of books on the subject of physiological control and regulation by Grodins (1) and Riggs (2), both in 1963, and Milhorn (3) in 1966.

The Applied Mathematics Division, Directorate of Mathematical Sciences, AFOSR is currently sponsoring a research program in this area. This program includes work by Professor Sumner N. Levine of the State University of New York at Stonybrook, Professor E. I. Jury of the University of California, Berkeley, Professor Edwin B. Stear of the University of California, Los Angeles, and Professor George H. Myers of New York University.

Professor Levine has produced valuable results in the regulatory mechanisms underlying protein synthesis, having investigated both linear and nonlinear models. Some of the predictions of these models agree with experimental data, and results appear to account for some of the features of adaptive enzyme formation. Significant work has also been accomplished in the study of renal electrolyte regulation. This work is directed toward establishing a mathematical model of the kidney and associated regulation of the body electrolyte system. Dr. Levine's research also includes

investigation into the theory of enzyme amplifiers as applied to blood coagulation, and work on the theory of stimulus electrodes which can be used as pacemakers in the heart. The publications produced by Dr. Levine are listed in the references.(4-17)

Professor Jury has produced results in the area of neuron modeling. (18, 19) He has shown that a neuron model is obtained which can exhibit the main properties of the sensory receptors. A sufficient number of parameters are presented in the definition of the pulse frequency modulators, which can be adjusted to fit the particular neural element to be simulated. Some of the properties of the sensory receptors, such as the gradient threshold and adaptation, are exhibited by the modulator only because it is time-varying.

Dr. Jury is now attempting to extend the results to multineuron elements, i.e., neurons connected in cascade or parallel, or a combination of both. By performing such a study, he can gain deep insight into information processing in the neurons. Finally, the model obtained in this work can be simulated on a digital computer, which will permit the latter to aid in the study of complex neuron connections.

Professor Stear has been conducting research on the mathematical modeling of the thyroid gland. This work involves studying the feedback mechanism of hormonal control systems. (22, 23)

Professor Myers, in his work, has applied the techniques of the Kalman Filter to the determination of the heart-rate control system in a mammal. Such a technique provides an elegant method for considering control systems with many interacting variables. Computer programs are being prepared to test the predictive methods of such a theory using experimental data obtained from other sources. Some of Dr. Myers' work are given in the references. (24-35)

One of the more prominent areas of physiological control and regulation involves the endocrine glands and their hormonal secretions. The control and regulatory aspects of the endocrine glands and their related hormones and systems have been recognized and understood qualitatively for some time. One now sees the widespread use of the word, "feedback," and the related concept of feedback control in the vast literature on endocrine function. However, quantitative mathematical and control-system theoretical models of these systems have been developed only recently, beginning in the mid-1950's. Moreover, it was not until the pioneering research of Dr. Yates and his colleagues at Stanford University that the true potential of quantitative mathematical control-system theoretical models of endocrine control and regulation became widely recognized and accepted by endocrinologists. Since that time there has been rapidly increasing activity on the part of both control engineers and medical researchers in the mathematical modeling of the control and regulatory aspects of the various endocrine functions.

As a result of this interest and activity, the Directorate of Mathematical Sciences and the Directorate of Life Sciences, both of AFOSR, along with the University of California at Los Angeles, the University of Southern California, the California Institute of Technology, and the Metabolic Dynamics Foundation sponsored a Conference on Hormonal Control Systems in Health and Disease which was held in the Inn at Rancho Santa Fe, California, in October 1967. This Conference was devoted to mathematical modeling and the control-system theoretical aspects of hormonal control systems under physiological and pathological conditions. The four main endocrine systems covered were the adrenocortical function, glucose homeostasis, the thyroid function, and the gonadal function.

The Conference was an interdisciplinary working meeting involving engineers, applied mathematicians, biochemists and medical scientists. Equal time was devoted to the physiological aspects, and to mathematical modeling and the control-system theoretical aspects of the four hormonal control systems. The results of the Conference were: (1) a clear assessment of the status of research on these hormonal control systems; (2) a delineation of those aspects in which the applications of mathematical modeling and control-system theory will be most beneficial; and (3) a delineation of those areas in which currently available mathematical-modeling techniques and control-system theory are inadequate for the study of hormonal control systems.

The Proceedings of this Conference should be available early this year. (36)

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